ELECTRICAL ENERGY CONSERVATION AND PEAK DEMAND REDUCTION POTENTIAL FOR BUILDINGS IN TEXAS: PRELIMINARY RESULTS

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ABSTRACT

This paper presents preliminary results of a study of electrical energy conservation and peak demand reduction potential for the building sector in Texas. Starting from 1980 building stocks and energy use characteristics, technical conservation potentials were calculated relative to frozen energy efficiency stock growth over the 1980-2000 period. The application of conservation supply methodology to Texas utilities is outlined, and then the energy use and peak demand savings, and their associated costs, are calculated using a prototypical building technique. Representative results are presented, for residential and commercial building types, as conservation supply curves for several end use categories; complete results of the study are presented in Ref. 1.

INTRODUCTION

The Public Utility Commission (PUC) of Texas has recently recognized the need to develop a standardized approach to the assessment of conservation and peak demand reduction potentials and the tools for such an analysis. Thus, the Center for Energy Studies at The University of Texas at Austin, working jointly with Lawrence Berkeley Laboratory (LBL), was contracted to conduct a preliminary analysis of the technical potential for electrical energy conservation and peak demand reduction in the building sector of Texas. The study used the conservation supply potential methodology developed at LBL (2, 3), in which the basis of a conservation supply potential curve is the Cost of Conserved Energy (CCE) for a given conservation measure. The cost of conserved energy is the annual (amortized) cost of implementing the measure divided by the annual energy savings of the measure. The amortization is carried out over the lifetime of the measure, or a shorter period acceptable to the investor. A conservation supply curve is a plot of the cost of conserved energy versus the potential savings (or peak demand reduction), accumulated over the building stock, of a set of efficiency investments assumed to be made on the building stock for a geographic region. The intent of a supply curve is to identify potentials, without regard to method of implementation, and as such, supply curves are not forecasts.

Although the study assessed both technical and policy/program issues (1), only the technical issues are reported in this paper. The starting place was the state's present electric load characteristics as documented in a recent PUC forecast of future demand in Texas (4). Potentials were calculated for a 20-year horizon from 1980-2000.

This paper summarizes the methodology used and presents results for representative building types and conservation measures that were studied. Building types accounting for only 18% of residential and 18% of commercial electricity use are reported here; complete results are presented in Ref. 1.

USE OF ELECTRICITY IN BUILDINGS IN TEXAS

A baseline energy use and peak demand for 1980 was chosen as the reference against which we developed the conservation potentials. Each prospective conservation or peak load reduction measure was applied to aggregate building stocks in Texas as the 1980 stocks were projected, assuming a frozen energy efficiency, to the year 2000.

Residential and commercial buildings in Texas accounted for electrical energy sales of 103.4 billion kilowatt hours (BkWh) in 1980 (4). Our analysis of conservation measures was applied to all of the Texas residential building stock, aggregated by three single-family categories (called SFD-1, SFD-2, and SFD-3) and one multifamily category (MFD) that are described in the next section. However, because of time constraints, in the commercial building category we considered only office buildings (OFF), retail stores (RET), and educational buildings (EDUC) that make up about 45% of the commercial building electric energy use. Figures 1 and 2 show the breakdown of 1980 statewide annual electricity consumption and peak demand, respectively, for these building types (5, 6).

Sources of statewide data on building stocks and energy use characteristics are spotty and incomplete; however, preliminary estimates of the needed data were compiled from several sources. Building stock and energy use data for the 1980 base year were established from a combination of Department of Energy/Energy Information Administration (DOE/EIA) sources, supplemented by census data and utility data. Data on residential buildings for the Southern US census region are published in the Residential Energy Consumption Survey (RECS) (5) published by the DOE/EIA. These data include regional-aggregate and building-average energy use by fuel type and

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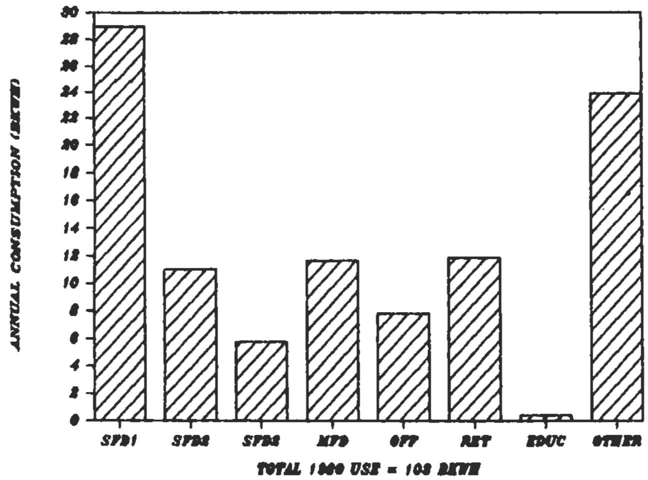

Fig. 1. Texas electricity consumption in 1980 base year by building type.

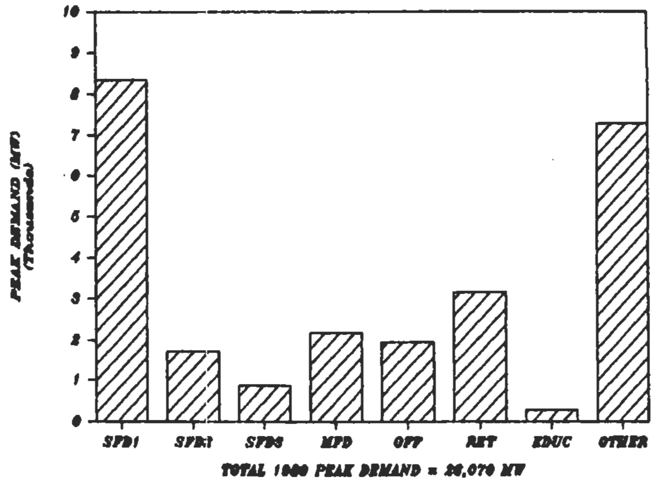

Fig. 2. Texas peak demand in 1980 base year by building type.

type of dwelling, as well as utility bills and building characteristics. For commercial buildings we used similar data from the Nonresidential Buildings Energy Consumption Survey (NBECS) (6) published by the DOE/EIA. In this document total buildings, average size per building, and energy consumption per building area and per employee are given by building type and fuel type for the Southern US census region. However, no breakdowns of data are available by state.

To obtain aggregate Texas building stocks, we used residential (7) and commercial (8) census data for 1980 in conjunction with the RECS and NBECS data. By combining census data for the number of employees in Texas with data on energy use per employee and building area per employee from NBECS, we estimated the building areas for the state by building type. Texas utility data were then used to develop the distribution of buildings by fuel type, peak demand diversity factors, building thermal integrity, climate zone, and appliance saturations. Building stock growth rates were estimated from regional population and employment census data. Also, energy audit data from the Bonneville Power Authority (9) were used for additional appliance and lighting saturations where these characteristics were deemed not to be regionally sensitive.

From the multiple data sources described above we used building stock data and energy use profiles generated by our prototypical building models to calculate total electrical energy use and peak demand in the residential and commercial building sectors. These aggregate numbers were adjusted to match actual 1980 PUC statewide totals for electrical energy use and coincident (summer) peak demand to establish a consistent reference for the conservation potentials.

APPLICATION OF METHODOLOGY TO TEXAS

CALCULATION OF CONSERVATION POTENTIALS

Conservation and peak load reduction potentials were calculated using realistic assumptions about the thermal integrity of the buildings and about their lighting, appliances, and heating/cooling equipment. Potential energy savings were calculated using a prototypical building concept. To generate the supply curves, the projections of energy savings potentials were summed over the building population by applying the savings for the prototypical buildings, using an eligible fraction, to the building stock represented by that prototype. The eligible fraction is an estimate that takes into account the portion of the stock to which the measure has already been applied and the portion for which it is physically impossible to implement the measure.

A key characteristic of the supply curves is that the cumulative energy savings (or peak demand reductions) were calculated relative to the baseline (year zero) building energy efficiency that was assumed frozen over the 20-year analysis period. Although the building stock would be expected to improve in energy efficiency as a result of market forces and other natural means, the potentials calculated included these improvements plus those that might be captured through energy conservation or regulatory programs.

Another significant characteristic of the supply curves is that annual savings were calculated on an incremental basis, ranked by the CCE. That is, the CCE of each measure was calculated assuming that the previous measures in the set had been implemented. Thus, the sequence in which measures are implemented is important. Our approach was to assume that measures are implemented in the optimum economic sequence within each measure category; the measure with the lowest CCE was done first. However, this is not always the case and variations will be explained as they arise.

A further problem arises when a set of alternative measures, such as shading devices, addresses the same load component. In such cases, the CCE was compared within the set, and only the measure of lowest cost was assumed to be implemented.

Finally, only the technical cost to the consumer, i.e., the life-cycle cost for material and labor to the building owner or operator, was used for each measure. Program costs to a utility or government to induce the implementation were not included.

In developing supply curves for peak demand reduction, our approach was to assess the summer peak load reduction effect for each measure on each prototypical building using the DOE-2 hourly building energy analysis program (10). This identified the summer peak hour demand. A 30% peak load diversity factor, obtained from Texas utility data, was then applied.

PROTOTYPICAL BUILDINGS

The most important building types, based on energy intensity and stockwide energy use, were selected. Existing commercial building prototypes developed in ASHRAE Special Project 41 (11) were used. These models included DOE-2 input files that reflected as-built conditions of actual buildings that were judged to be typical in their design. The residential prototypes were modifications of prototypes developed for a residential energy audit manual prepared for the State of Texas (12), adjusted using Houston Lighting and Power energy audit results. The commercial building base case models were adjusted to reflect ASHRAE Standard 90-75, which was considered to be an average of a wide range of building vintages.

Three single-family residential classes were identified representing old, recent, and new construction practices and the medians of three ranges of typical house sizes. Detailed descriptions of the following seven prototypical buildings are given in Ref. 1.

1. Single-family dwelling 1 (SFD-1); 63% of the single-family residential electricity use. Pre-1961 characteristics, poorly insulated (R-11 ceiling, R-2 walls), pier-and-beam construction, 1000 ft^2, representing all old frame construction, and mobile homes of all ages; includes a room air conditioner in 80% of the stock.
2. Single-family dwelling 2 (SFD-2); 24% of the single-family residential electricity use. 1961-73 characteristics (R-19 ceiling, R-11 walls), slab-on-grade construction, 1630 ft^2, representing recent trends in tract housing in the 1200-2000 ft^2 range; includes central air conditioning.
3. Single-family dwelling 3 (SFD-3); 13% of the single-family residential electricity use. 1974-present characteristics and new construction (R-19 ceiling, R-11 walls), slab-on-grade, 2600 ft^2, representing current construction (possibly 2-story) homes larger than 2000 ft^2; includes central air conditioning.
4. Multifamily dwelling (MFD). A large apartment complex was used to represent all apartments, duplexes, condominiums, and townhomes.
5. Office building (OFF). A medium size (3-story, 49,000 ft^2) office building was used to represent all office space including high rise, single story, and office parks.
6. Retail store (RET). A two-zone strip store (12,000 ft^2) was used to represent all retail establishments.
7. Educational building (EDUC). A 113,000 ft^2 high school was used to represent all elementary, secondary, and higher education institutions.

A climate sensitivity study indicated that three climate zones for residential and two for commercial buildings would adequately represent weather-dependent energy use patterns:

Zone 1 - Coastal prairies, lower valley, and part of pine belt -- subtropical climate, hot/humid summers, mild winters (represented by Houston)

Zone 2 - Central/north central -- hot/dry summers, moderate winters (represented by Ft. Worth)

Zone 3 - Panhandle -- hot/dry summers, cold winters, large diurnal and seasonal variations, higher elevations (represented by Lubbock)

Based on 1980 census data for all 254 Texas counties, the population and economic activity distribution is approximately 33% in Zone 1, 62% in Zone 2, and 5% in Zone 3.

The three single-family residential building types were used to represent the range of house vintages; commercial buildings and multifamily housing were not distinguished as to age. Two fuel type classifications were used: all-electric and mixed-fuel. All-electric buildings use electricity for all end uses whereas mixed-fuel buildings use electricity for cooling, lighting, and miscellaneous equipment and fossil fuel for heating and domestic hot water.

CHARACTERISTICS OF BASELINE PROTOTYPICAL BUILDINGS

The aggregate stock and average electricity use characteristics of the baseline (1980) prototypical buildings are shown in Tables 1 and 2. The base case energy use for each prototype was calculated using the Computerized Instrumented Residential Audit (CIRA) (13) energy analysis program for the single-family residences and DOE-2 (10) for the multifamily and commercial buildings. However, DOE-2 was used to calculate peak loads for all the prototypes.

CONSERVATION MEASURES CONSIDERED AND THEIR COSTS

The sets of conservation measures considered for each building type, categorized by end use component, are listed below. Residential building measures were grouped by the categories of heating and cooling, and appliances. Commercial building measures were grouped by envelope, HVAC systems, and lighting/miscellaneous equipment categories. Coupled effects (e.g., cooling implications of lighting) were accounted for within each measure category. Measures that presented significant modeling problems or that were judged to have minor impact on electrical energy use or peak demand were not analyzed in this study.

The cost components considered for both new and retrofit applications included design and analysis, materials, labor, maintenance, and financing; a 10% real discount rate was used for all cases. Because of difficulties in working around existing mechanical, structural, or electrical systems, the retrofit costs usually differ from those in a new building. Although implementation costs may vary between remote locations and urban areas, these variations were neglected.

CONSERVATION SUPPLY POTENTIAL RESULTS

Each of the conservation measures studied was simulated in succession, in order of increasing CCE for the seven building types described above. Although only representative results are presented here for SFD-2, the office building, residential appliances, and office lighting, complete results for the other building types are given in Ref. 1. (Because the single-family dwelling stock distribution is under review, the SFD-2 results are preliminary and subject to later refinement.) The

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Table 1. Baseline 1980 Electric Energy Use-- Residential Buildings

						1980 ENERGY USE			
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
			1980 STOCK			PER UNIT		TOTAL	
BLDG TYPE	HEAT FUEL	CLIMATE ZONE	# UNITS	SF/UNIT	TOT SF (MILLION)	CONS (KWH)	PEAK (KW)	CONS (BKWH)	PEAK (MW)
Type 1 residence; 1000 sq ft, pre 1961 vintage, no AC									
SFD1	ELEC	1	38565	1008	38.87	12416	1.00	0.48	27
SFD1	ELEC	2	68026	1008	68.57	15563	1.00	1.06	48
SFD1	ELEC	3	6066	1008	6.11	21397	1.00	0.13	4
SFD1	GAS	1	202466	1008	204.09	2678	1.00	0.54	142
SFD1	GAS	2	357139	1008	360.00	2678	1.00	0.96	250
SFD1	GAS	3	31845	1008	32.10	2678	1.00	0.09	22
Type 1 residence; 1000 sq ft, pre 1961 vintage, with AC									
SFD1	ELEC	1	154260	1008	155.49	17518	4.39	2.70	474
SFD1	ELEC	2	272106	1008	274.28	20299	3.74	5.52	712
SFD1	ELEC	3	24263	1008	24.46	24867	3.99	0.60	68
SFD1	GAS	1	809863	1008	816.34	7436	4.39	6.02	2489
SFD1	GAS	2	1428555	1008	1439.98	7067	3.74	10.10	3740
SFD1	GAS	3	127380	1008	128.40	5801	3.99	0.74	356
Type 2 residence; 1630 sq ft, 1961-1973 vintage									
SFD2	ELEC	1	44551	1630	72.62	33895	5.55	1.51	173
SFD2	ELEC	2	78507	1630	127.97	35885	5.27	2.82	290
SFD2	ELEC	3	7093	1630	11.56	39564	4.51	0.28	22
SFD2	GAS	1	111769	1630	182.18	20449	5.55	2.29	434
SFD2	GAS	2	196957	1630	321.04	19434	5.27	3.83	727
SFD2	GAS	3	17796	1630	29.01	16628	4.51	0.30	56
Type 3 residence; 2600 sq ft, post 1973 vintage									
SFD3	ELEC	1	28470	2600	74.02	39359	7.30	1.12	145
SFD3	ELEC	2	50169	2600	130.44	39957	7.07	2.00	248
SFD3	ELEC	3	4533	2600	11.79	40216	6.26	0.18	20
SFD3	GAS	1	31215	2600	81.16	27698	7.30	0.86	160
SFD3	GAS	2	55008	2600	143.02	26445	7.07	1.45	272
SFD3	GAS	3	4970	2600	12.92	23406	6.26	0.12	22
Multifamily									
MFD	ELEC	1	132164	1270	167.85	16979	4.33	2.24	401
MFD	ELEC	2	254486	1270	323.20	17851	4.41	4.54	786
MFD	GAS	1	108262	1270	137.49	15740	4.33	1.70	328
MFD	GAS	2	208088	1270	264.27	15236	4.41	3.17	643
			4854572		6639.23	TOT RES USE		57.40	13059
						1980 ACTUAL		59.30	13367

Table 2. Baseline 1980 Electric Energy Use-- Commercial Buildings

						1980 ENERGY USE			
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
			1980 STOCK			PER BLDG		TOTAL	
BLDG TYPE	HEAT FUEL	CLIMATE ZONE	# EMPL	SF/EMPL	TOT SF (MILLION)	CONS (KWH/SF)	PEAK (W/SF)	CONS (BKWH)	PEAK (MW)
Office building; 49,000 sq ft									
OFF	ELEC	1	188861	348	65.72	25.3	9.0	1.66	413
OFF	ELEC	2	362881	348	126.28	26.0	9.0	3.28	792
OFF	GAS	1	125908	348	43.82	22.3	8.2	0.98	251
OFF	GAS	2	241921	348	84.19	21.9	8.2	1.85	483
Retail store; 12,000 sq ft, strip retail									
RET	ELEC	1	137501	769	105.74	28.3	10.2	3.00	753
RET	ELEC	2	192720	769	148.20	27.7	10.3	4.10	1067
RET	GAS	1	99569	769	76.57	27.2	10.2	2.08	548
RET	GAS	2	140233	769	107.84	24.8	10.2	2.68	772
Educational building; 113,000 sq ft									
EDUC	ELEC	1	1667	1172	1.95	9.9	8.7	0.02	12
EDUC	ELEC	2	3203	1172	3.75	9.8	8.2	0.04	22
EDUC	GAS	1	12224	1172	14.33	9.2	8.7	0.13	87
EDUC	GAS	2	23488	1172	27.53	7.9	8.2	0.22	159
Miscellaneous buildings									
OTHER	ALL	ALL	635083	669	991.87	24.1	10.5	23.90	7290
			1530176		805.92	TOT COMM USE		43.94	12650
						1980 ACTUAL		44.00	12701

annual energy saved with each measure was calculated using CIRA for the residence and DOE-2 for the office building. Calculations of energy savings for residential appliance and office lighting measures were taken from previous studies (9) and modified for application in Texas.

The conservation measures considered for SFD-2 and the resulting electrical energy and peak demand savings are listed in Table 3 for heating and cooling end uses. Only results for Climate Zone 2 (Central - Ft. Worth) are included; the other climates are reported in Ref. 1. The potential conserved energy results are summed over the building stock and plotted in Fig. 3, where measures applied to both all-electric and mixed-fuel houses are included. This supply curve includes costs, eligible fractions, and building stocks for both new and retrofit applications. Note that the first four measures can be accomplished for a cost of conserved energy of less than 7¢/kWh. For measures less than 7¢/kWh, approximately 1.2 BkWh/yr[1] can be saved for all residences in this category and climate region.

Table 4 lists the envelope measures considered for the office building and the resulting electrical energy savings and peak load reductions; the related supply curve is shown in Fig. 4. Measures applied to both all-electric and mixed-fuel offices are included. The HVAC measures for the office are shown separately in Table 5 and Fig. 5. Note that the HVAC measures are considerably more cost effective than are the envelope measures. Whereas five HVAC measures are achievable at less than 7¢/kWh, only three envelope measures are achievable at less than this CCE. A 1.0 BkWh/yr potential savings for envelope measures and a 3.0 BkWh/yr potential savings for HVAC measures are indicated at under 7¢/kWh.

When selected appliance conservation measures are applied statewide to all single-family and multifamily residences, shown in Table 6 and Fig. 6 for refrigerators and freezers, the results are striking. Here all measures considered have low costs to the consumer and therefore result in low costs of conserved energy, even though the savings for each measure are modest. Note that all measures have costs of conserved energy below 5¢/kWh and result in potential savings of 14 BkWh/yr.

Similar but not as dramatic results occur for lighting measures in office buildings. As was the case of residential refrigerators and freezers, these climate-independent measures apply statewide and are summed over all the office building stock as shown in Table 7 and Fig. 7. Note that three no-cost, operational measures potentially could save 0.67 BkWh/yr; the remaining measures could save an additional 0.33 BkWh/yr at less than 6¢/kWh. Lighting measure results for other building types are presented in Ref. 1.

The final set of curves (see Tables 3-7 and Figs. 8 and 9) show representative peak demand reduction results for office building envelope and HVAC measures. Fig. 8 shows that for envelope measures applied to all office buildings statewide, two measures that address glazing solar gains and heat losses could potentially reduce peak demand by 170 MW at a cost of less than \$1700/kW. Similarly, Fig. 9 shows that for HVAC systems measures applied to all office buildings, four measures could potentially reduce peak demand by 370 MW at a cost of less than \$1700/kW. Thus, in office buildings HVAC measures have about twice the peak demand reduction potential of envelope measures. For SFD-2 heating and cooling measures (not shown here), the peak reduction potential is 860 MW at a cost of less than \$1100/kW.

[1]Note that a nominal large power plant (1000 MW) supplies approximately 5 BkWh/yr.

Table 3. Heating and Cooling Conservation Measures for SFD-2 (1630 sq ft), Climate Zone 2 (Fort Worth) only

SUPPLY CURVE LEGEND

BASE CONSUMPTION: 35885 KWH (All-elec) 19434 KWH (Gas heat)
BASE PEAK: 5.3 KW
Savings are calculated from CIRA runs

END USE CATEGORY: Heating and Cooling

ID CODE	NOTES	DESCRIPTION	COST ($) NEW	COST ($) RET	LIFE (YRS)	SAVINGS KWH	SAVINGS KW	CCE (RETROFIT) $/KWH	CCE (RETROFIT) $/KW
Electrically heated buildings									
SEEH201		Auto 5 F htg & clg setback	120	120	20	4179	0.00	0.003	0
SEEH202		Seal ducts	62	80	20	763	0.00	0.013	0
SEEE203		Interior shades (reflective)	375	375	10	1081	0.00	0.060	0
SEEE204		Ceiling insulation - add R19	200	754	20	1382	0.09	0.065	8378
SEAE205		Exterior Shade	613	613	17	872	1.21	0.090	507
SEEE206		Double glazed windows	589	589	20	612	0.00	0.115	0
SEAH207		High eff AC	700	4000	20	3264	2.30	0.147	1739
SEEE208		Caulking-attic & ceiling	300	386	15	307	0.00	0.171	0
SEEE209	1	Caulking-walls	375	499	15	265	0.00	0.255	0
SEEE210	1	Weatherstripping-windows	50	92	5	41	0.00	0.712	0
Fuel heated Buildings									
SEFH201	2	Auto 5 F htg & clg setback	120	120	20	2169	0.00	0.007	0
SEFH202	2	Seal ducts	62	80	20	324	0.00	0.030	0
SEFE203	2	Interior shades (reflective)	375	375	10	581	0.00	0.112	0
SEFE204	1,2	Ceiling insulation - add R19	200	754	20	168	0.09	0.538	8378

NOTES:
1. Measure does not appear on supply curve due to its relatively high CCE or peak reduction.
2. Measure applies to gas heated buildings and is plotted on the same supply curve as other measures (gas heated measure has a higher CCE than the corresponding measure for an electrically heated building.

Table 4. Envelope Conservation Measures for Office Building (49,000 sq ft), All Climate Zones

SUPPLY CURVE LEGEND

BASE CONSUMPTION: ELECTRICALLY HEATED 1265400 KWH (Ft Worth)
1230800 KWH (Houston)
FUEL HEATED 1067100 KWH (Ft Worth)
1083600 KWH (Houston)
BASE PEAK: 436.0 KW (Ft Worth) 437.1 KW (Houston)

END USE CATEGORY: Envelope

Savings are calculated from DOE-2 runs

ID CODE	NOTES	DESCRIPTION	COST ($) NEW	COST ($) RET	LIFE (YRS)	SAVINGS KWH	SAVINGS KW	CCE (RETROFIT) $/KWH	CCE (RETROFIT) $/KW
Electrically heated buildings									
ONEE201	1	Window films	12139	12139	20	66600	20.80	0.022	584
ONEE202		Interior shades (refl)	14699	14699	20	41300	8.90	0.043	1652
ONEE203	3	Wall insulation	5024	37877	20	6300	0.60	0.719	63128
ONEE204	2	Double glazed windows	32070	44898	20	95900	12.60	0.056	3563
ONEE205	3	Light color roof treatment	12776	17545	15	1100	0.40	2.165	43863
Fuel heated buildings									
ONFE001	1	Window films	12139	12139	20	56500	20.80	0.026	584
ONFE002		Interior shades (refl)	14699	14699	20	28500	8.90	0.062	1652
ONFE003	3,2	Wall insulation	5024	37877	20	1500	0.60	3.019	63128
ONFE004		Double glazed windows	32070	44898	20	39200	12.60	0.137	3563
ONFE005	3	Light color roof treatment	12776	17545	15	1300	0.40	1.832	43863

NOTES:
1. Measure was intended to represent several possible options for solar shade control. The other options (window screens, fixed shading devices, etc) were predicted to have a higher CCE based on a preliminary sensitivity analysis.
2. Measure was simulated out of order based on CCE.
3. Measure does not appear on supply curve due to its relatively high CCE or peak reduction.

CONCLUSIONS AND RECOMMENDATIONS

Although this paper presents only a few preliminary results of our full study, they are representative of electrical energy savings and peak demand reductions that potentially could be achieved in Texas. These preliminary results support the following conclusions:

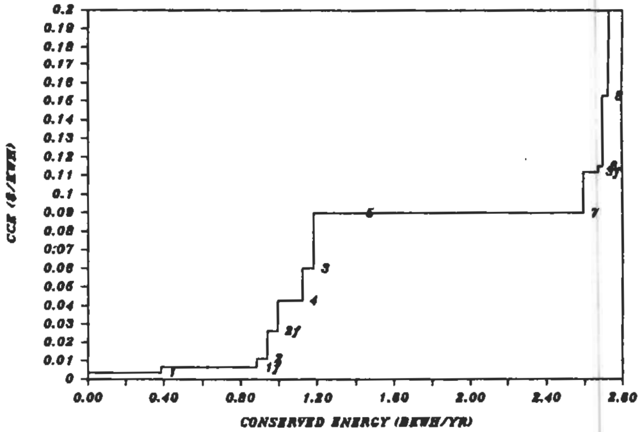

Fig. 3. Conservation supply curve for heating and cooling measures in SFD-2 (1630 ft^2), Climate Zone 2 (Ft. Worth) only.

NOTES: 1. New and retrofit measures applied over total building stock using appropriate eligible fractions.

2. Measures applied to both all-electric and mixed-fuel buildings.

3. Numbers on curve correspond to last 2 digits of ID CODES in Table 3; "f" denotes mixed-fuel case.

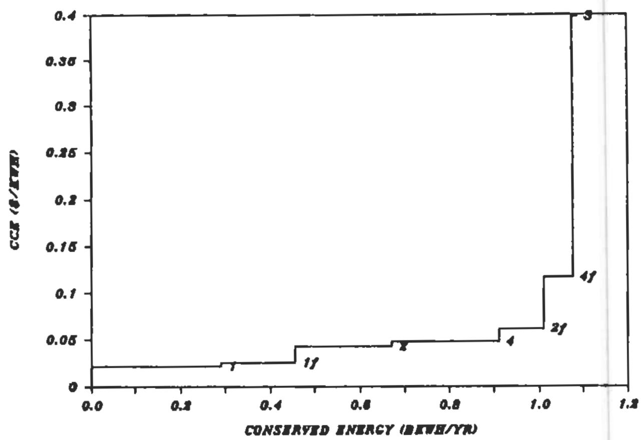

Fig. 4. Conservation supply curve for envelope measures in office building (49,000 ft^2), all climate zones.

NOTES: 1. New and retrofit measures applied over total building stock using appropriate eligible fractions.

2. Measures applied to both all-electric and mixed-fuel buildings.

3. Numbers on curve correspond to last 2 digits of ID CODES in Table 4; "f" denotes mixed-fuel case.

1. Considering building stocks that account for less than 20% of Texas electrical energy use, the potential for electrical energy savings at less than the current average price of electricity (6-7¢/kWh), is approximately 20 BkWh/yr in the year 2000, which is equivalent to the approximate output of 4 large power plants. These potential savings also represent about 14% of the year 2000 projected Texas annual electricity use at frozen efficiency.

Similarly, the potential for peak demand reduc-

Table 5. HVAC Systems Conservation Measures for Office Building (49,000 sq ft), All Climate Zones

SUPPLY CURVE LEGEND

BASE CONSUMPTION: GAS HEATED - 1067100 KWH (Ft Worth)
1083600 KWH (Houston)
ELEC HEATED - 1265400 KWH (Ft Worth)
1230800 KWH (Houston)
BASE PEAK: 436.0 KW (Ft Worth) 437.1 KW (Houston)

END USE CATEGORY: HVAC systems — Savings are calculated from DOE-2 runs

ID CODE	NOTES	DESCRIPTION	COST ($) NEW	COST ($) RET	LIFE (YRS)	SAVINGS KWH	SAVINGS KW	CCE (RETROFIT) $/KWH	CCE (RETROFIT) $/KW
ONEH201	1	Conversion to VAV	15600	19000	20	283700	40.60	0.008	468
ONFH201	1	Conversion to VAV	15600	19000	20	237500	40.60	0.010	468
ONEH202	2,3	Hydronic heat pump loop	24332	24332	20	129500	0.00	0.023	-
ONFH203		Evaporative cooling	6102	37968	20	120500	26.70	0.038	1422
ONFH204		Reduce system size	1520	1700	20	7000	3.50	0.029	486
ONFH205	3	Controls package	6695	6695	20	28800	0.00	0.028	-
ONFH206	5	Higher COP cooling equip	20439	30172	20	16200	12.20	0.223	2473
ONFH207		Higher eff fan motors	6587	6587	10	6700	4.10	0.171	1607
ONFH208	4,5	Chilled water storage	45000	55000	20	0	54.00	-	4815

NOTES:

1. Both fuel heated building and electrically heated building results appear on the same supply curve. Because of the additional electricity savings in electrically heated buildings those measures always appear first.
2. This measure was compared to measure #1 for system conversion. The more cost effective of the two (VAV conversion) became the installed system type for subsequent measures.
3. Measure did not show any peak reduction and does not appear on the peak supply curves.
4. Measure did not show consumption reduction and does not appear on supply curves.
5. Measure does not appear on supply curve due to its relatively high CCE or peak reduction.

Table 6. Refrigerator/Freezer Conservation Measures for All Single and Multifamily Residences, All Climate Zones

SUPPLY CURVE LEGEND

BASE CONSUMPTION: See notes below

END USE CATEGORY: Refrigerators

LABEL DESCRIPTION	COST ($) NEW	COST ($) RET	LIFE (YRS)	SAVINGS KWH	SAVINGS KW	CCE (RETROFIT) $/KWH	
Refrigerators							
11 SBS - buy efficient model	16	16	19	1292	-	0.002	-
8 BFAD - buy efficient model	19	19	19	1484	-	0.002	-
6 TMF - buy efficient model	22	22	19	911	-	0.003	-
9 BFAD - CPES improvement	11	11	19	326	-	0.004	-
12 SBS - CPES improvement	4	4	19	109	-	0.005	-
4 PAD - buy efficient model	35	35	19	675	-	0.006	-
1 SDM - buy efficient model	22	22	19	180	-	0.015	-
2 SDM - CPES improvement	18	18	19	115	-	0.019	-
10 BFAD - 1987 improvement	75	75	19	275	-	0.033	-
13 SBS - 1987 improvement	100	100	19	350	-	0.035	-
7 TMF - 1987 improvement	75	75	19	257	-	0.036	-
5 PAD - 1987 improvement	60	60	19	180	-	0.041	-
3 SDM - 1987 improvement	50	50	19	130	-	0.047	-
Freezers							
14 CMD - Buy efficient model	12	12	21	771	-	0.002	-
15 CMD - CPES improvements	13	13	21	168	-	0.009	-
16 UMD - Buy efficient model	33	33	21	975	-	0.004	-
17 UMD - CPES improvements	12	12	21	118	-	0.012	-
18 UAD - Buy efficient model	25	25	21	1860	-	0.002	-
19 UAD - CPES improvements	20	20	21	258	-	0.009	-

NOTES:

Refrigerators	Basecase unit energy consumption (KWH/YR)	Freezers	Basecase unit energy consumption (KWH/YR)
SBS = Side By Side	2890	CMD = Chest Manual Defrost	1087
PAD = Partial Auto Defrost	1407	UMD = Upright Manual Defrost	1303
SDM = Single Door Manual	818	UAD = Upright Automatic Defrost	2298
BFAD = Bottom Freezer, Auto Def	3048		
TMF = Top Mount Freezer	1980		

CPES = Consumer Products Efficiency Standards

1987 improvement = High efficiency compressor + increased wall insulation avail. by 1987

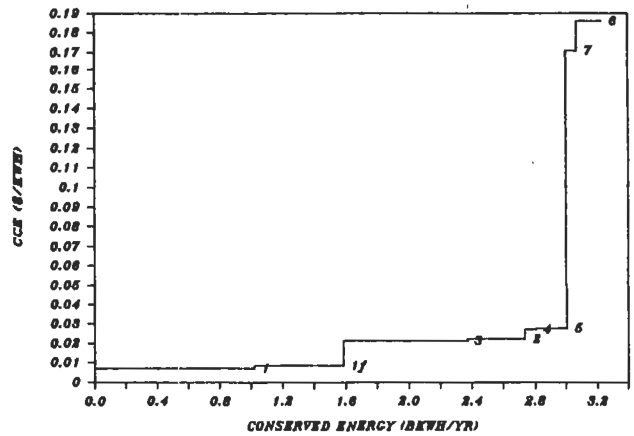

Fig. 5. Conservation supply curve for HVAC system measures in office building (49,000 ft^2), all climate zones.

NOTES:
1. New and retrofit measures applied over total building stock using appropriate eligible fractions.
2. Measures applied to both all-electric and mixed-fuel buildings.
3. Numbers on curve correspond to last 2 digits of ID CODES in Table 5; "f" denotes mixed-fuel case.

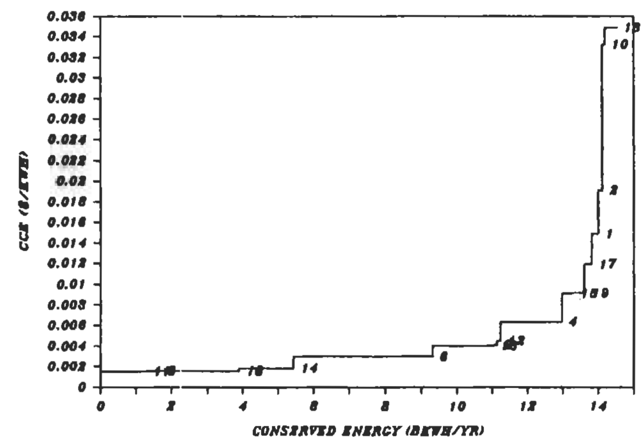

Fig. 6. Conservation supply curve for refrigerator/ freezer measures in all residences, single and multifamily, all climate zones.

NOTES:
1. Assumes total refrigerator/freezer stock is replaced at 5% per year over 20 year period.
2. Numbers on curve correspond to LABELS in Table 6.

tion for the same modest fraction of the building stocks considered here (but excluding residential appliances and office lighting) is approximately 1400 MW at less than $1700/kW, the present cost of a coal-fired plant.

2. For commercial buildings, HVAC systems measures have considerably greater potential for energy and peak demand savings than do envelope measures.

Proceedings of the Second Symposium on Improving Building Systems in Hot and Humid Climates, College Station, TX, September 24-26, 1985

Table 7. Office Building Lighting Conservation Measures, All Climate Zones

SUPPLY CURVE LEGEND   BASE CONSUMPTION: 6.90 KWH/SF-YR

END USE CATEGORY: Lighting

			COST ($)		LIFE	SAVINGS		CCE (RETROFIT)	
ID CODE	LABEL	DESCRIPTION	NEW	RET	(YRS)	KWH/SF-YR	W/SF	$/KWH-SF	$/KW
OEEL003	3	Flo-Delamp - No replacement	0.00	0.00	14	3.45	-	0.000	-
OEEL004	4	Flo-Delamp - Dummy replacement	0.00	0.00	14	3.45	-	0.000	-
OEEL005	5	Flo-Delamp - Reactive replacement	0.00	0.00	14	2.31	-	0.000	-
OEEL006	6	Low wattage fluorescent	0.05	0.05	5	0.69	-	0.023	-
OEEL001	1	High efficiency core/coil	0.19	0.19	14	0.69	-	0.039	-
OEEL002	2	Electronic solid state ballast	0.56	0.56	14	1.38	-	0.057	-

NOTES: Flo-Delamp = Fluorescent delamping
All savings, costs, and costs of conserved energy are per square foot of floor area

Because the statewide data base for Texas building stock and energy use characteristics is incomplete, we recommend that a high quality data base be established so that the results of this study can be refined and extended.

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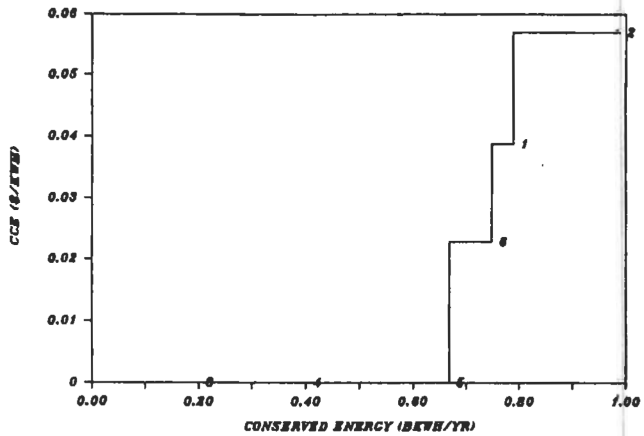

Fig. 7. Conservation supply curve for lighting measures in all office buildings, all climate zones.

NOTES: 1. New and retrofit measures applied over total building stock using appropriate eligible fractions.

2. Numbers on curve correspond to last 2 digits of ID CODES in Table 7.

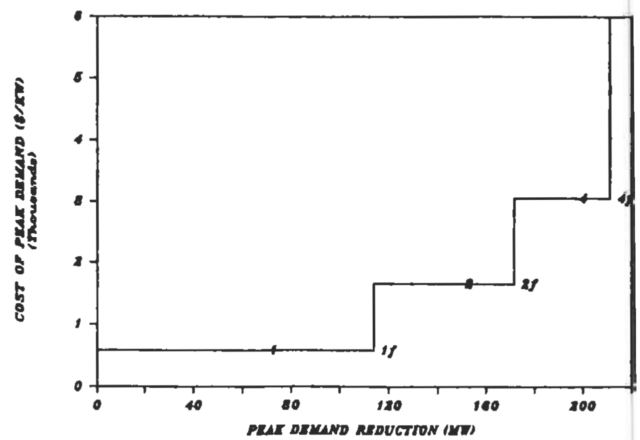

Fig. 8. Peak demand reduction curve for envelope measures in office buildings, all climate zones.

NOTES: 1. New and retrofit measures applied over total building stock using appropriate eligible fractions.

2. Measures applied to both all-electric and mixed-fuel buildings.

3. Numbers on curve correspond to last 2 digits of ID CODES in Table 4; "f" denotes mixed-fuel case.

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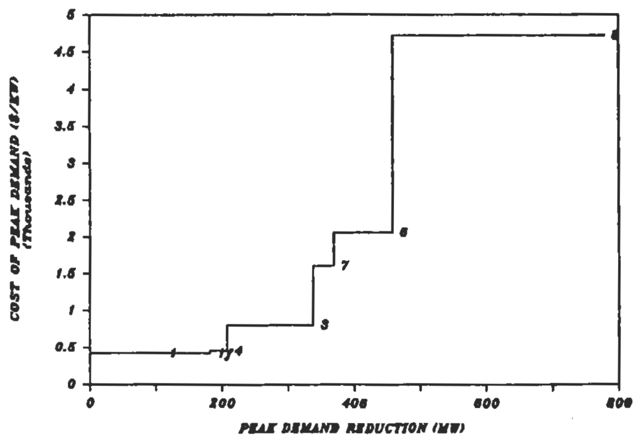

Fig. 9. Peak demand reduction curve for HVAC system measures in office buildings, all climate zones.

NOTES: 1. **New and retrofit measures applied over total building stock using appropriate eligible fractions.**

2. **Measures applied to both all-electric and mixed-fuel buildings.**

3. **Numbers on curve correspond to last 2 digits of ID CODES in Table 5; "f" denotes mixed-fuel case.**

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